

Jefferson Lab
FEL Program Status Report
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FEL Users Meeting and
Laser Processing Consortium Workshop

March 10—11, 2004



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FEL/Light Source Program Highlights (Since March 2003 Meeting)

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- The FEL Upgrade achieved first light in June 2003 and is being commissioned to full power in the IR
- First user experiments should begin this summer
- 1 kW UV-FEL Upgrade on track for completion in early 2005
- THz beamline project is underway funded by the US Army
- JLab FEL on DOE-BES Roadmap for THz-IR science
(Workshop held by DOE/NSF/NIH in February, 2004)
- Industrial partners (thru IAB) making good progress on microfabrication, laser ablation/deposition



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FEL/Light Source Program Highlights (Since March 2003 Meeting), cont'd.

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- **Proposal for laser bioscience/biomedicine applications center in the works (UVA, Harvard Mass General, EVMS, ECU)**
- **FEL technology development continues to be supported and funded by the US Navy, AFRL, DOD-JTO**



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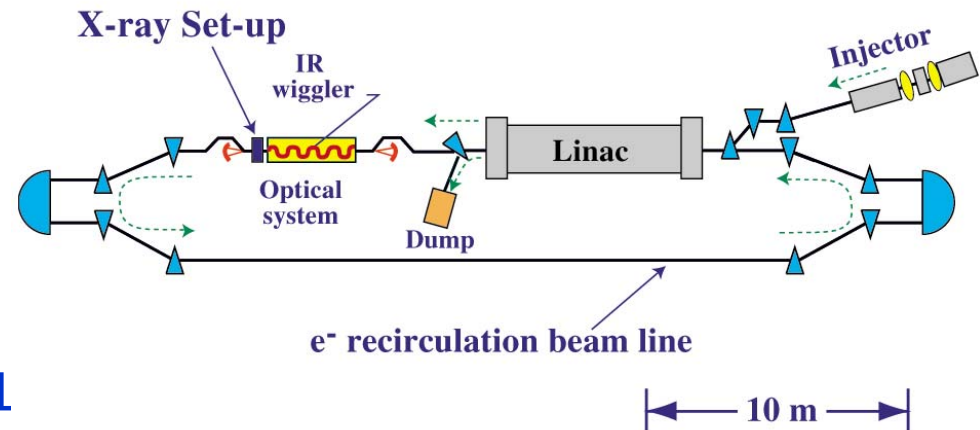


FEL Program Goals

- Development, demonstration and application of high average power and energy efficient lasers (superconducting accelerator driven FELs) for applications of interest to:

IR Demo Layout

1. Science
2. Industry
3. Defense



- Key attributes of the JLab FEL
 - High average power (1 - 10 - 100 kW)
 - Broad tunability (0.25 μm - 15 μm)
 - Unique time structure (75 MHz, sub piossecond)

FEL Program Timeline

Evolution of Design:

- 1 kW IR FEL Demo 1996–1998
- IR Demo operations 2000–2001
- 10 kW IR Upgrade 2000–2003
 - 10 kW IR Upgrade operations 2004–
- 1 kW UV Upgrade 2002–2004
 - 1 kW UV Upgrade operations 2005–

In planning stage:

- 50—100 kW technology development 2004–2006
- User Lab Expansion



FEL Program Stakeholders

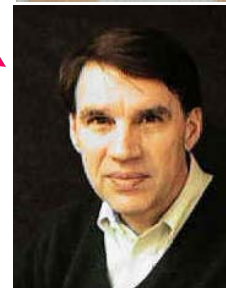
- **Scientific community** (FEL Program Advisory Committee – FEL PAC)
 - Always new frontiers when any parameter of a scientific tool improves by 10x
 - The 1 kW Demo was the most powerful tunable laser in the world by:
 - 10 (UV)
 - 10^2 (IR)
 - 10^5 (THz)
- **Defense community** (Maritime Technical Advisory Committee – MTAC)
 - Navy: technology demonstration for directed energy applications (all electric drive tunable to atmospheric windows)
 - Air Force: high volume UV laser microfabrication
- **Industrial Community** (Industrial Advisory Board-IAB)
 - Materials processing at 10-100 kW where cost per photon is commercially viable - (1-10¢/kJ)
 - Surface modification
 - Microfabrication
 - Pulse laser deposition/ablation



FEL - Program Advisory Committee

Philippe Guyot-Sionnest, University of Chicago, Physics →
Richard Haglund, Vanderbilt, Physics, Materials Science →
Trevor Sears, Brookhaven National Lab., Chemistry →
John Sutherland, East Carolina University, Biology →

• **Joining us at this meeting**



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Maritime Tactical Advisory Committee (MTAC)

MTAC Members

- Vice Admiral Albert J. Baciocco, Jr., US Navy (Retired)

Chairman, MTAC

- Dr. Alan Berman, NRL Director (Retired)
- Vice Admiral Kenneth C. Malley, US Navy (Retired)
- Vice Admiral J.T. Parker, US Navy (Retired)



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Industry Advisory Board (IAB)

Alan Todd, IAB Chairman,

Advanced Energy Systems

Michael Kelley, LPC Chairman,

College of William and Mary/JLab

Patrick Fleming

3M Central Research Laboratories

James Greer

PVD Products

Martha Harrell

Smartclic

Henry Helvajian

Aerospace Corporation

Daniel Henkel

Pall Trinity Micro Corp.

Gregory Kessel

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Gary Neiheisel

AK Steel

David Rice

Northrop Grumman Newport News

Richart Slusher

Lucent Technologies

•Joining us at this meeting



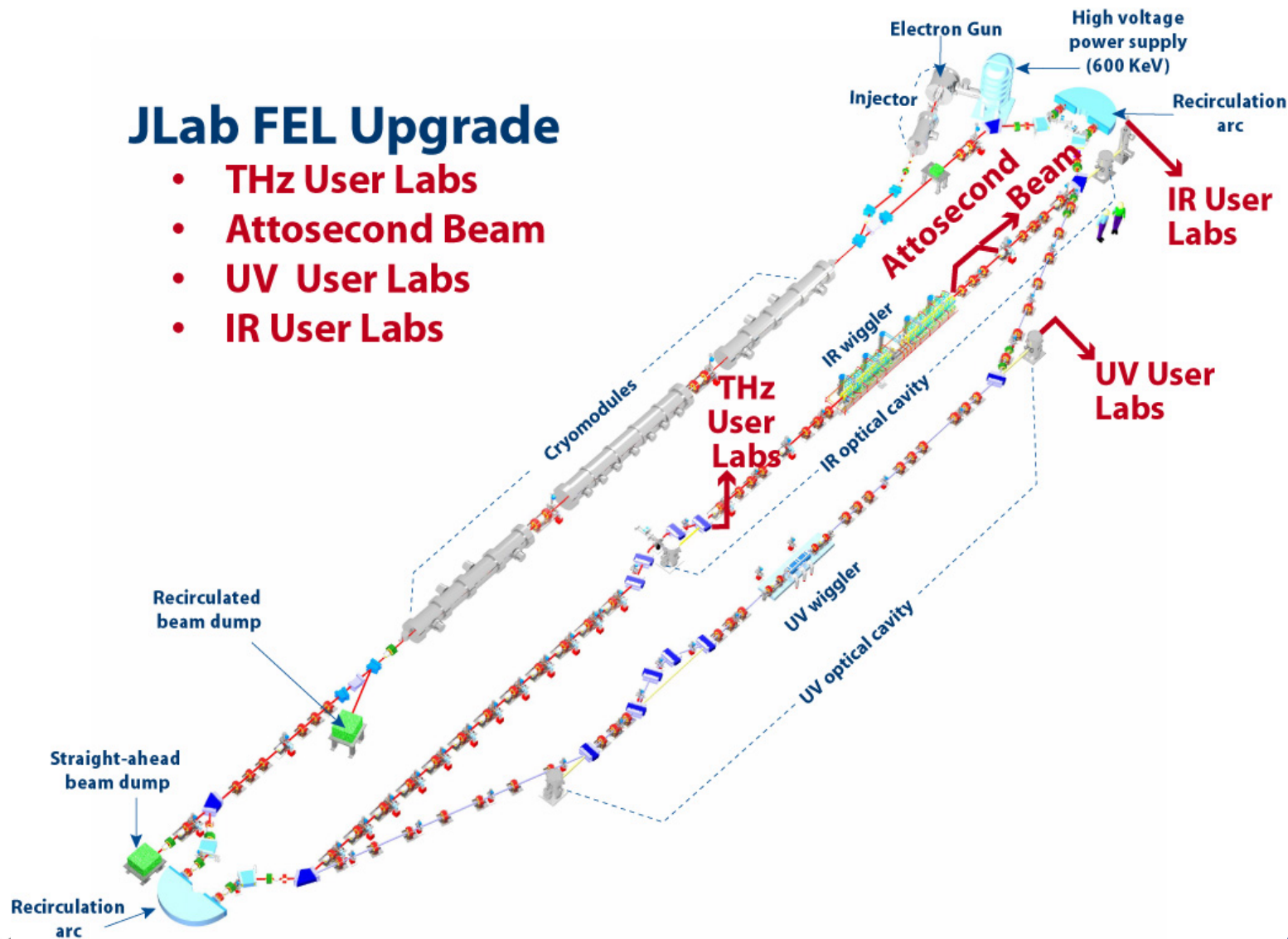
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10 kW IR and 1 kW UV

JLab FEL Upgrade

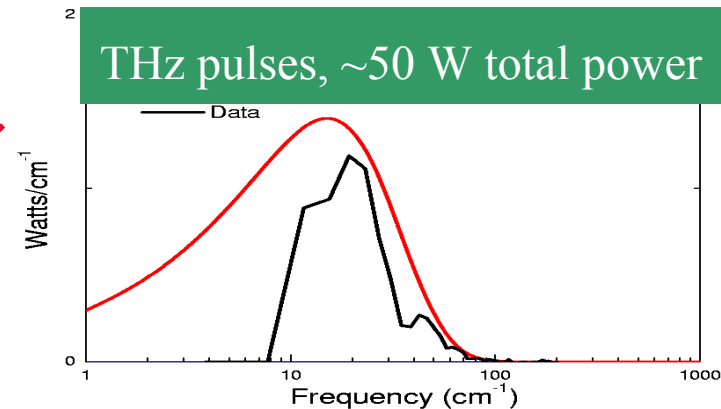
- THz User Labs
- Attosecond Beam
- UV User Labs
- IR User Labs



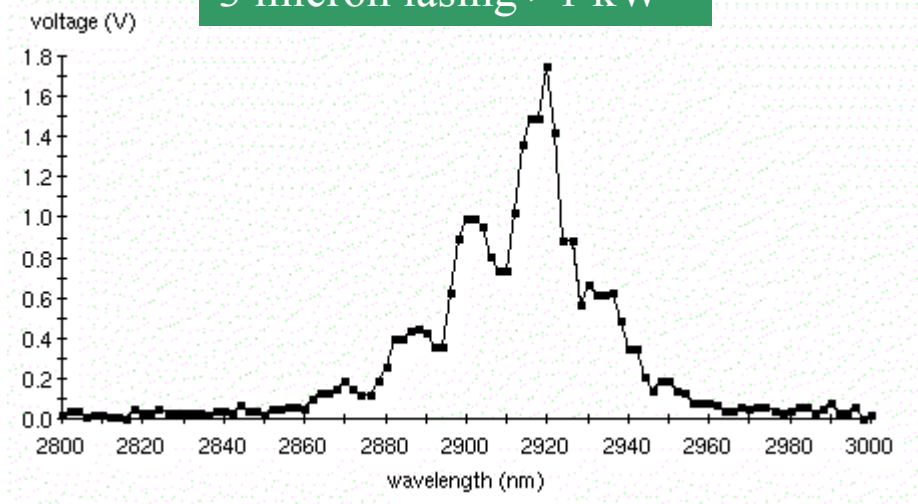
Simultaneous production of 3 μm , THz, and 10 keV X-ray femtosecond pulses

- 800 fsec pulses at 37.4 MHz
- Synchronized to $\ll \text{psec}$ levels (same beam!)
- All three wavelengths at world class fluxes

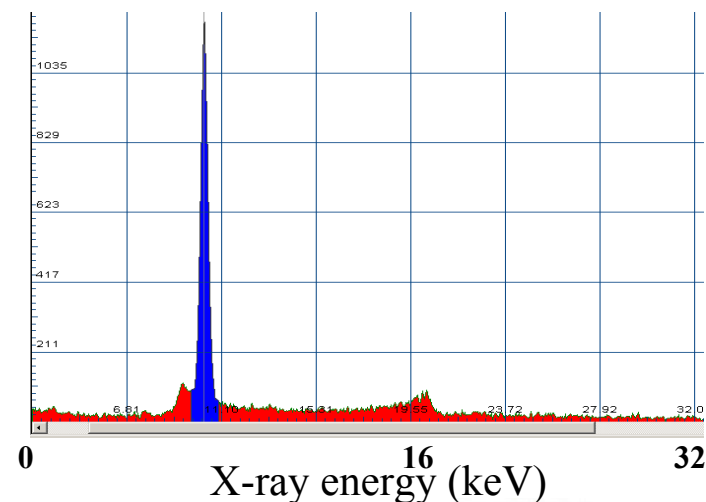
Sample



3 micron lasing $> 1 \text{ kW}$



10 keV X-ray $> 10^5 \text{ ph/sec/0.1\% BW}$



FEL User Results (2000-2001)

- The first user runs for the FEL using the 1 kW IR Demo produced significant new science
 - Suite of measurements of hydrogen defects in Si (G. Luepke, et al.)
 - High rate, high quality magnetic film deposition (A. Reilly, et al.)
 - High rate, unique structure nitrides (P. Schaff, et al.)
 - Resonant ablation of polymers (M. Kelley and R. Haglund)
- These results were different than comparable work with conventional lasers → advantage from high power, short pulse and/or tunability



Planned FEL User Experiments

- Important new experiments are being proposed:
 - Extending previous work to higher powers
 - Taking advantage of higher pulse energies
 - Taking advantage of more user friendly tunability and extended range
- At the 2003 and (following-up at this 2004 Users' Meeting) new proposals:
 - Laser-induced chemistry (UVA)
 - Biomolecules (Princeton, CWM, EVMS)
 - Ablation
 - Atomic physics (ODU)
- New and potential users are invited to submit “letters of Intent” (more from Gwyn Williams)



DOE Basic Energy Sciences Roadmap

- JLab invited to present to BES (NSF/NIH) workshop for planning THz Science (Feb. 2004)
- Committee recommendations
 - THz/IR science “critical”
 - Additional National workshops will be held to develop the user community
 - DOE should invest in energy recovered linac (ERL) technology demonstrated by the JLab FEL
- More from Gwyn Williams and Jim Horwitz



Helios X-ray Lithography Consortium

- Workshops held Jan. 2003 and Nov. 2003 to define a program to further develop proximity x-ray lithography
- Attended by representatives from 6 companies
- Workshop attendees have formed a consortium to propose a modest development program based on recommissioning the Helios compact x-ray source at JLab

- More from Gwyn Williams



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Bioscience/Biomedicine Collaboration

- Lasers have been applied to bioscience and biomedicine since shortly after their invention in the 1960's
 - Spectroscopy
 - Laser surgery
 - Laser treatments
- Vanderbilt and Duke University FEL Centers and the Harvard Mass General Wellman Labs have established program in this area
- Proposal being developed with UVA, Mass General, EVMS, and ECU for formation of a laser bioscience center and dedicated User labs at the FEL Facility

Potential applications

- Spectroscopy in model systems
- Dermatological treatments
- Photo dynamic therapy
- Optical tomography
- UV-near UV photodamage studies



Progress on Industrial Collaboration

Jefferson Lab's Industrial Advisory Board (IAB) has guided FEL proposal development and industrial applications since 1991

IAB focusing on developing business case for cost effective, high volume processing when two criteria are met

- Power is available for production quantities (10-100 kW)**
- Cost/photon is commercially viable (1-10¢/kJ)**



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Progress on Industrial Collaboration, Cont'd.

Work in Progress:

- **PLD working group activities (NRL, CWM, Vanderbilt, PLD, Inc.)**
- **“Pulse stacker” funded by ONR (M. Kelley, CWM/JLab, PI) is in fabrication**
 - **Allows trade-off between pulse energy and repetition rate**
 - **Expands utility of the FEL for pulse laser deposition/ablation**
- **Versatile Microfabrication Work Station being designed/built by Aerospace Corp. (AFRL funding), Henry Helvajian, PI for delivery to the FEL Users Facility in April 2005**



Aerospace Microengineering Station

Facility and related R&D by Henry Helvajian, et al.,
Aerospace Corporation

- Multiwavelength laser processing
- Automated CAD to CAM file transfer
- Automated patterning 100-150 mm wafer scale processing and step-and-repeat processing to be located at FEL site
- Automated, process development facility to be located at the Aerospace Corporation
- Continues transition of processes, tool control software and refinements to FEL facility
 - Including fundamental measurements of ps laser material interaction physics



Path Forward on FEL Technology Development with DOD Support

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- The Office of Naval Research (ONR) has been the primary stakeholder in the 1 kW and 10 kW FEL Projects
- ONR/Naval Sea Systems Command (NAVSEA) and the Air Force Research Laboratory (AFRL) support the present FEL Upgrade commissioning effort

Navy Path Forward

- 5-year development plan for higher power FELs is in place (2004–2008)
- JLab has proposed highpower upgrades of the JLab FEL that:
 - Builds upon the 10kW upgrade
 - Incorporates present R&D on FEL technology (electron gun, cryomodules, optics)
 - Expands the scientific and industrial utility of the FEL User Facility
 - higher average power
 - lower cost/photon
 - higher repetition rate (75-750 MHz)
- Collaboration in place (NRL, LL) for continuation of laser damage (lethality) studies and laser propagation (NRL) studies



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Opportunities at this Users' Meeting

- Existing, new and potential users of the FEL Upgrade should interact at this meeting
- Discuss experience and collaboration opportunities with prior users
- Submit “letters of intent” and (later) proposals for FEL beam time (procedure on the Web: www.jlab.org/FEL/)
- Submit supporting proposals for user equipment to funding agencies (DOD, DOE, NSF, NIH, NASA, etc.)



Summary

- Users from the 2000-2001 FEL User run did a great job of establishing the scientific utility of this type of laser for:
 - High sensitivity spectroscopy
 - Laser ablation
 - Laser deposition
- Exciting proposals have been submitted for using the FEL Upgrade and we solicit others
- JLab FEL technology has been recognized as a unique source of THz-IR radiation (BESAC)
- The DOD (Navy, Air Force and Army) continues to fund and support FEL technology development at JLab
- Materials processing applications are maturing with the:
 - AFRL funded, Aerospace Corp. Microfabrication Station
 - PLD working group
- The 10 kW IR Upgrade should be available for first users later this summer (including THz beamline)
- The 1 kW UV Upgrade is planned for operations next Summer



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Commonwealth of Virginia

City of Newport News

Laser Processing Consortium



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